

# ULDB Recovery Systems

**Christopher Shreves** 

546/Carrier Systems Branch



**Review** 

**Recovery Systems** 

# **Objectives**

- Decelerate payload from termination to safe impact
- Provide impact attenuation for land recovery
- Provide flotation for water recovery
- Provide location aids for remote areas



### Descent

# Current method is unfurled flat circular chute in flight train

- + Simple design
- + Low risk
- + Inexpensive
- Impact accuracy ~3.22 km radius
- Unacceptable material degradation due to environmental exposure
- Weight: 215 kg Cost: \$12,566



**Recovery Systems** 

### Descent Alternatives

#### Enveloped Flat Circular

Unfurled chute in flight train, enveloped in protective material

#### Packed Flat Circular

Better material protection, but more complicated

### Packed Two-Stage System

Improved accuracy via quick first-stage descent

#### Guided Parafoil

Highest impact accuracy, but very complicated and expensive

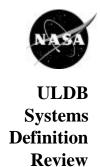


**Recovery Systems** 

### Descent Alternatives

### **Enveloped Flat Circular**

- + Simple
- + Low deployment risk
- + Slightly lower opening shock load
- + Small weight penalty
- More expensive
- No improvement on impact accuracy
- Potential problem with canopy/sleeve friction
- Untried design
- Weight: ~238 kg Cost: ~\$17,070



### Descent Alternatives

#### **Packed Flat Circular**

- + Inexpensive
- + Small weight penalty
- + Lower opening shock load
- + Common design
- Higher complexity
- No improvement on impact accuracy
- Weight: ~218 kg Cost: ~\$14,070



**Recovery Systems** 

## Descent Alternatives

### Packed Two-Stage System

- + Small weight penalty
- + Lower opening shock load
- + Impact accuracy improved to ~400 m radius
- + Common design
- More expensive
- Higher complexity
- Weight: ~229 kg Cost: ~\$18,070



Recovery Systems

### Descent Alternatives

#### **Guided Parafoil**

- + Small weight penalty
- + Lower opening shock load
- + Impact accuracy improved to 200 m radius
- Initially much more expensive
- Much higher complexity
- New technology
- Weight: ~227 kg
- Initial cost: ~\$130,000 Refurb: ~\$10-15K



**Recovery Systems** 

### Descent Alternatives

Trade Study						
	Maximum	Flat Circular As Is	Enveloped Flat Circular	Packed Flat Circular	2-Stage System	GPS-Guided Parafoil
Performance	10	5	6	6	8	9
Weight	10	8	6	8	7	7
Size	5	3	3	4	4	3
Cost	8	7	4	6	5	2
Schedule	8	8	7	7	6	5
Power	5	5	5	5	4	3
Interfaces	5	4	4	3	3	2
Hazmat	5	5	5	5	4	3
Risk	10	9	6	7	6	4
Total	66	54	46	51	47	38

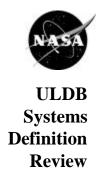
Packed flat circular scores higher, if greater impact accuracy required then use packed two-stage system



> Recovery Systems

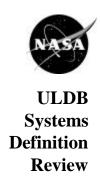
# Descent Alternatives

Characteristics					
	Flat Circular As Is	Enveloped Flat Circular	Packed Flat Circular	2-Stage System	GPS-Guided Parafoil
Weight, kg	215	238	218	229	227
Cost, \$	12,566	17,070	14,070	18,070	130,000
Impact Radius, km	3.2	3.2	3.2	0.4	0.2
Max Load, g	7	7	7	7.4	3



# Opening Load Attenuator

- Opening shock of parachute imparts high *g*-levels on payload
- Balloon Branch has device that dissipates shock energy via ripping of stitches in flight-train webbing
- Ground tested & test-flown
- Use as needed
- Weight: 16-31 kg Cost: \$5,500



# Land Impact Options

#### **PASSIVE ATTENUATION DEVICES**

Crush Pads

Cardboard & styrofoam; simple, cheap, balloonqualified; environmental exposure effects unknown

• Aluminum Honeycomb Pads

Rocket-qualified, higher absorbed energy/cu-ft, higher cost (\$60/cu-ft)

#### **ACTIVE ATTENUATION DEVICES**

Air Bags

Compact, expensive, higher risk, level of effort; double-duty as water impact bags?

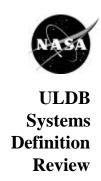


**Recovery Systems** 

# Land Impact Options

Trade Study					
	Maximum	Crush Pads	Нопеусоть	Air Bags	
Performance	10	10	10	9	
Weight	10	9	9	7	
Size	5	3	4	4	
Cost	8	7	6	4	
Schedule	8	8	8	5	
Power	5	5	5	4	
Interfaces	5	4	4	3	
Hazmat	5	5	5	4	
Risk	10	9	9	7	
Total	66	60	60	47	

No clear winner between simple solutions of crush pads and aluminum honeycomb



# Water Impact Options

#### **PASSIVE FLOTATION DEVICES**

Sealed Structural Volume

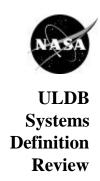
Structural tubing sealed to provide positive buoyancy

• Foam-Filled Structural Volume

Replace air with foam; lower risk than sealed volume, slightly heavier

Strap-On Floats

Off-the-shelf floats/buoys strapped to structural members; fewer mechanical interface problems



# Water Impact Options

#### **ACTIVE FLOTATION DEVICES**

Structure-Mounted Inflatable

Deployable air bag attached to gondola; compact, higher risk, higher cost

Tethered Inflatable Buoy

Deployable air bag tethered to submerged gondola; semi-qualified on rocket payloads, fewer mechanical interface issues



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# Water Impact Options

Trade Study						
	Maximum	Sealed Volume	Foam-Filled Structure	Strap-O <sub>n</sub> Floats	Hard-Mount Inflatable	Tethered Inflatable
Performance	10	10	10	10	10	10
Weight	10	10	9	9	8	8
Size	5	3	3	3	4	4
Cost	8	7	6	6	4	4
Schedule	8	7	8	8	5	5
Power	5	5	5	5	4	4
Interfaces	5	2	2	3	4	5
Hazmat	5	5	5	5	4	4
Risk	10	7	10	10	7	7
Total	66	56	58	59	50	51

Strap-on floats win due to ease of interface



**Recovery Systems** 

## Location Aids

- In case of unplanned termination, need location aids for recovery in remote areas
- Sounding Rocket Program has successfully used DF radio beacons, ARGOS transmitters, strobe lights

	ARGOS	164.X MHz	242.0 MHz
Xmitter Cost, \$	3,380	500	1,711
Xmitter Weight, g	273	64	65
Range, km	N/A	32	160
Signal Life,			
days/kg of batteries	7.0	2,897	13.2

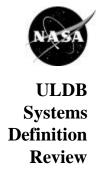


# Additional Systems

# Options being persued

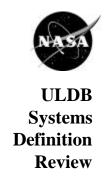
- Dropsonde development
  - Deployable GPS sonde to give "near real time" wind measurements for descent vector determination
- Automated chute cut-away

Investigation of approach to automatically cut chute after Earth impact



### Recommendation

- Packed flat circular parachute system
- Opening shock load attenuator (optional)
- Strap-on flotation devices (optional)
- Crush pads (Aluminum honeycomb optional)
- ARGOS transmitter and strobe
- Estimated system cost: \$24,155
- Estimated system weight:
  224 kg without options, 291 kg with options



# Cost & Weight Breakdown

	Weight, kg	Cost
Parachute System	218	\$14,070
<b>Shock Attenuator (opt)</b>	16	\$5,500
<b>Land Impact Attenuator</b>	2.3	\$180
Water Recovery (opt)	51	\$200
<b>Location Aids</b>	3.3	\$4,205
TOTAL	291	\$24,155